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Global Trends in IPO Methods:

Book Building vs. Auctions

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Global Trends in IPO Methods: Book Building vs. Auctions

The U.S. book building method has become increasingly popular for initial public offerings (IPOs) worldwide over the last decade, whereas IPO auctions have been abandoned in nearly all of the many countries in which they have been tried. I offer an explanation for this pattern by modeling book building, discriminatory auctions and uniform price auctions in an environment where the number of investors and the accuracy of investors' information is endogenous. For all methods, the seller's expected proceeds are equal to the expected value of the shares sold minus the expected costs of information acquisition. However: 1) the expected number of shares sold, and thus expected proceeds, is higher for book building, because auctions carry a greater risk of undersubscription; and 2) book building, unlike auctions, allows issuers to control spending on information acquisition, and thus to control expected proceeds. Since more control and less risk are beneficial to all issuers, the advantages of book building's allocational flexibility may explain why global patterns of issuer choice are surprisingly consistent.

1. Introduction

Book building is the primary initial public offering (IPO) method in the U.S., but for decades it has generated controversy because it allows shares to be preferentially allocated. Investors complain that they are shut out of the allocation process and call for changes that will give everyone a "fair" chance. In 1999, WR Hambrecht responded to these complaints by offering U.S. issuers an alternative – a uniform price IPO auction, where shares are allocated based only on bids. Given the recent controversies about spinning, laddering and other questionable IPO allocation practices, some have argued that new issuers should be required to use an auction, rather than the traditional U.S. method [1]. Thus it is important to identify the differences between these two methods. In this paper, I demonstrate two key advantages of book building over auctions: that it reduces risk for both issuers and investors, and that it allows the issuer to control information costs and thus to control the degree of underpricing.

The primary difference between book building and other IPO methods is that the book building method gives underwriters control over the allocation of shares. In contrast, auctions require the allocation of shares to be based on current bids, without regard to any past relationship between certain bidders and the auctioneer, and they are usually open to more or less everyone. Similarly, the public offer (a.k.a. fixed price, universal offer or open offer) method normally includes "fairness rules" which limit discrimination.

It is the ability to allocate shares freely that makes "book building" (the advance gathering of indications of interest) possible. Under an auction or public offer system, underwriters are free to do road shows and to ask for indications of interest. However, without the ability to make allocations dependent on the information reported, there is no way for underwriters to give investors the incentive to accurately report their information, as was first discussed in Benveniste and Spindt (1989) and Benveniste and Wilhelm (1990).

Thus, it is allocation flexibility that distinguishes book building from other IPO methods[2]. This flexibility includes the ability to pre-commit to specific allocation (and pricing)

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1 See, for instance, "The value of trust", The Economist, 6/8/2002, Vol. 363 Issue 8276, p65.

2 Book building gives issuers flexibility in both allocation and pricing of IPO shares, except that all shares must sell for the same price (the "one price rule"), while many types of auctions leave the issuer no choice in either allocation or pricing (except perhaps through the setting of a reservation price). A unique feature of many IPO auctions is that the seller may have discretion in setting the price. A dirty auction, a.k.a. "leaving something on the table", is an auction where the issuer is allowed to choose an offering price strictly below the market-clearing price. In other words, the price may be set below the maximum level that would allow all shares to be sold (which means that shares must be rationed). Dirty auctions have been used in Australia, Belgium, Finland, France,

rules, such as those of an auction. One example of this is WR Hambrecht, which was able to begin offering their "Open IPO" sealed bid, uniform price "dirty" auction in the U.S. without any changes in legislation. The question for U.S. regulators, then, is not whether to allow auctions, but whether to mandate them. To answer this question, we must examine the role of flexibility in the allocation of IPO shares.

From a regulatory standpoint, the auction and public offer methods are both subsets of book building in which the underwriter pre-commits to a specific allocation rule. In practice, underwriters that are given full discretion seldom pre-commit voluntarily to one of these two subsets. Instead, they choose to explicitly collect information from an established group of investors, aggregating that information and incorporating it into the price. They use allocations strategically, from a long term perspective, rather than pre-committing to a simple rule.

In this paper, I model both book building and two types of sealed bid auctions for the same environment, one in which the number of investors and the accuracy of investors' information is endogenous. The two auction types are discriminatory (pay what you bid) and uniform price[3], both of which have been used for IPOs in many countries. I show that, for both the book building and auction models, the seller's expected revenue[4] is equal to the expected value of the shares sold minus the aggregate information acquisition costs. In other words, for both methods, IPO shares are underpriced by just enough to compensate informed investors for their evaluation costs.

Thus it may appear that the methods are equivalent in this environment, but the apparent similarities mask two key differences. First, the issuer/underwriter has substantial control over information acquisition through book building, but little or no control in an auction. Since underpricing must be sufficient to compensate investors for their spending on evaluation, book building gives the issuer greater control over the expected proceeds from the

Hungary, New Zealand, the United Kingdom and the United States. Thus, many IPO auctions give the issuer as much pricing flexibility as in book building, leaving allocation flexibility as the primary difference.

3 In finance, uniform price (a.k.a. single price) auctions are sometimes mistakenly called Dutch auctions. A Dutch auction is an open (rather than sealed bid) descending price auction. A Dutch auction for multiple units involves selling the same item for many different prices and is in this sense closer to a discriminatory auction.

4 I will use the term seller's expected revenue because it is standard in the auction literature, although the funds received from a stock issue are proceeds, and not revenue.

issue. This control can be used either to minimize underpricing, or to induce investors to more carefully evaluate the issue, resulting in a more accurate issue price.[5]

In other words, book building gives issuers greater flexibility. For issuers with a strong preference for price accuracy, auctions may lead to too little evaluation and thus too much remaining uncertainty. On the other hand, for issuers whose primary goal is to minimize underpricing, auctions may lead to too many resources being spent on evaluation, with issuers paying for this through lower average bid prices. The disadvantage of auctions is not that they always lead to either too much or too little evaluation (or underpricing), it is that they seldom, except by chance, lead to the optimal level. Auctions are a "one size fits all" approach, whereas book building allows customized solutions.

The second difference between the two methods is that the expected number of shares sold is higher for book building, because there is a greater chance of undersubscription in an auction[6]. With book building, the underwriter co-ordinates the number of investors that will participate, guaranteeing that a sufficient number (but not too many) are involved. With an auction, an issuer simply sets the reservation price and waits to see what happens. Expected IPO proceeds are strictly higher for book building, holding constant the amount spent on information acquisition, because auctions sell fewer shares on average.

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[5] I show that the ability to control information expenditures is valuable even to an issuer that cares only about maximizing the proceeds of the issue (because book building allows the issuer to minimize underpricing in this case). However, there are many reasons why the issuer (and underwriter) would value accurate pricing of an issue. Sherman (2000) shows that an issuer preference for price accuracy arises endogenously if uninformed investors are more risk averse than informed investors. Other reasons include better investment choices, underwriter reputation, issuer signaling, aftermarket liquidity, and lawsuit avoidance (see Sherman and Titman, 2001). Last, for agency reasons, managers may feel that their future job performance is more likely to be judged fairly if the initial price is more accurate.

Moreover, whether or not one believes that the issuer *wants* this feedback, it is clear that book building *is* an information gathering process – that it involves an information flow from investors to the issuer and underwriter, as well as vice versa – because the final price and quantity of IPO shares depend on responses received during the book building process. Since it is relatively easy under book building to design an offering to discourage costly evaluation (by giving only small allocations to many outside investors), the fact that issues are allocated in a way that encourages evaluation suggests that the information is valued.

In the auction literature, it is well established that potential bidders sometimes pay to collect information. For example, test drilling can be very expensive but is often done before auctions of offshore oil tracts. The standard assumption in the auction literature is that the seller does not value the information collected. However, the auction of IPO shares is different from most auctions because the buyer and seller will have a continuing relationship – the buyers will become part-owners in the company, along with the sellers (who will still own shares and will continue to manage the firm).

[6] The type of undersubscription I consider here is the risk that there will be too few bidders simply by chance, independent of the quality of the issue. There is also the risk, with either book building or auction, that an issue will be undersubscribed because investors carefully considered the offering and didn't like it.

The lack of investor coordination in auctions leads to increased risk for both issuers and investors - both sides must make decisions without knowing how many bidders will choose to participate. Ex post, there may be too few entrants and the offering may fail, or there may be too many entrants that bid away all of the potential profits, preventing investors from recovering their information costs (see Levin and Smith, 1994). In my model, with risk neutral agents, only the possibility of undersubscription is priced. Auctions would be at even more of a disadvantage in a model with risk averse issuers and/or investors[7].

A third advantage of preferential allocations was identified in Benveniste and Spindt (1989) and Sherman (2000). The underwriter's discretion in allocating shares can be, and usually is, used to favor regular investors. This allows the underwriter to "average" returns over time, sometimes requiring investors to participate in the current offering in order to remain part of the group that will participate in future offerings. The threat of cutting investors off from future offerings can be used to reduce the chance that the current issue will fail, to give investors an incentive to evaluate and accurately report their information on the current issue and to reduce the average excess returns that investors may receive over time.

These three advantages of book building apply to all issuers, regardless of issuer characteristics such as quality, risk level or preference for price accuracy. These advantages must be weighed against the possible corruption (spinning, kickbacks, etc.) that might come with allowing underwriters to make preferential allocations, and with other advantages and disadvantages of book building relative to alternative methods. However, if the advantages identified here are sufficiently important, then the result is likely to be a corner solution, with all issuers choosing book building, since flexibility benefits all types of issuers.

While a formal test is beyond the scope of this paper[8], I have gathered information on the IPO methods used in more than 40 countries, in order to determine whether the choices of issuers are consistent with the predictions of this model. The pattern that emerges is, for the most part, a corner solution, at least for auctions relative to book building. Book building,

[7] The ability to co-ordinate entry also allows underwriters to eliminate the "winner's curse" faced by investors. This adverse selection problem, first noted for IPOs by Rock (1986), causes bidders in a discriminatory auction to lower their bids and requires the issuer in a public offer to underprice in order to attract uninformed investors (although Chowdhry and Sherman, 1996b, shows that the common practice of favoring small over large orders reduces this problem). With book building, if the investment bank handles many IPOs sequentially, it can prevent this adverse selection problem for uninformed investors by allocating a relatively fixed proportion of shares in each offering to a regular group of investors, preventing informed investors from "cherry-picking" only the best.

[8] It should be noted that a more formal test may not be possible, due to the lack of data on auctions and to the fact

which was rare outside North American in the early 1990s, is now common around the world, even in markets that U.S. investment banks have not yet managed to penetrate[9].

IPO auctions, on the other hand, have been tried repeatedly in many different countries, and most if not all countries have abandoned them. Some countries, such as Japan and arguably France, gave up auctions only after unrestricted book building was allowed. More commonly, countries such as Singapore, the U.K., Italy, Switzerland, Portugal and possibly Taiwan gave up auctions to return to public offer. The public offer method has lost considerable ground over the last decade but is still used regularly, mainly in small countries where IPOs are infrequent, and for smaller local issues in other countries. Although this paper focuses on the advantages of book building, it should be recognized that the auction method has been, at best, a distant third among IPO methods. To argue that the U.S. should mandate auctions for IPOs, one must first explain why auctions have been unpopular relative to *both* book building *and* public offer, with or without the involvement of U.S. investment banks.

Therefore, rather than a pattern of one method being more popular with, say, larger, higher quality, safer issuers, concentrated in certain industries, while another method is used for smaller, riskier issuers, mainly in other industries, the pattern has been that few or no issuers of any type choose IPO auctions when unrestricted book building is available. This has held true across many countries, cultures and market conditions, across variations in the regulatory and procedural details of the two methods, and regardless of whether the final decision was made by issuers or by regulators. The consistency of this pattern implies that there are significant advantages to allocation flexibility. This paper suggests two such advantages.

The rest of the paper is organized as follows. Section 2 reviews some of the most relevant literature. Section 3 contains models of both book building and the two types of auctions: 3.1 specifies the environment; 3.2 presents the book building model; 3.3 presents the

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that a corner solution is predicted.

[9] The original impetus for global experimentation with book building was the trend towards privatizations, since such offerings were often too large for the local market. U.S. investment banks have encouraged the spread of book building and have attempted to follow it into every market to which it has spread, but the book building method has succeeded even in markets where U.S. investment bankers have not, so the trend cannot be attributed entirely to U.S. investment banking pressure. The evidence indicates that regulators and issuers in many countries are willing to try new methods but do not cling blindly to them regardless of whether or not the methods work. For example, many countries adopted auctions because of academic research and the observation that auctions worked well in many situations. Even after incurring substantial costs in order to experiment with IPO auctions, these countries made further changes once auction problems developed. Thus, there's no basis for the argument that book building is used simply because other countries are unable or unwilling to judge for themselves and thus are forced to copy the U.S. method.

auction models; 3.4 compares the book building to the auction solutions; 3.5 compares the two auction solutions; and 3.6 discusses empirical implications regarding underpricing under the various methods. Section 4 compares the broad predictions of the model to international patterns in issue methods, particularly to the dominance of the book building method and the observed problems with IPO auctions. Section 5 is the conclusion.

2. Brief review of some of the most closely-related literature

This paper builds on previous models of the book building process by Benveniste and Spindt (1989), Benveniste and Wilhelm (1990), Sherman and Titman (2002) and Sherman (2000). Like Sherman and Titman (2002), this model has information acquisition and endogenous entry, but it extends past work by allowing the information's accuracy to be a continuous decision variable, and by characterizing the equilibrium when the underwriter has total control of pricing.

In the auction literature, relatively little work has been done on endogenous entry and information production in a common value setting. Notable exceptions are Hausch and Li (1993) and Harstad (1990), both of which consider only the single unit case. This paper contributes to the auction literature by modeling discriminatory and uniform price multi-unit auctions in a setting suitable for analyzing IPOs. One key characteristic of IPOs is that the shares are difficult (and therefore costly) to evaluate. There are no past analyst reports to read and no market price to observe. One must evaluate the top managers and their strategic plan, comparing them to their competitors, as well as forecasting the future of the industry and other factors. A second key feature of IPOs is that the number of potential entrants to the auction is extremely large relative to the number of bidders that the auction can profitably accommodate. For an IPO auction such as that offered by WR Hambrecht, the number of potential bidders easily exceeds 100 million.

Like Harstad, Chemmanur and Liu (2002) analyze information acquisition in auctions but only allow investors to choose whether or not to pay a fixed price to obtain a fixed signal. Both papers consider the effects of a reservation price although, unlike Harstad, Chemmanur and Liu do not give conditions for the optimal reservation price, do not consider endogenous entry and do not model both uniform price and discriminatory auctions. However, Chemmanur and Liu compare a uniform price auction to fixed price methods for IPOs. The trade-off in their model is that fixed price methods elicit more information production (similar to one of the

advantages demonstrated here for book building, except that their fixed price methods always lead to greater information acquisition) but do not allow the offering price to reflect investor demand, unlike their auction[10].

Biais and Faugeron-Crouzet (2002) also model IPO auctions, showing that a uniform price dirty auction can prevent tacit collusion among bidders and can truthfully elicit pre-existing information from investors in much the same way as book building. Similarly, Parlour and Rajan (2002) find a resemblance between dirty auctions and book building, showing that dirty auctions can reduce the winner's curse (eliciting more aggressive bids) under a variety of allocation rules, including some that allow the underwriter to discriminate between bidders. Last, Bulow and Klemperer (1998) show that it can be optimal in an auction to set a price at which there is excess demand.

Loughran, Ritter and Rydqvist (1994) were the first to examine broad patterns for IPOs across a number of countries, showing that underpricing of IPOs exists to some extent in virtually all countries and all issue methods. Cornelli and Goldreich (2001) examine a unique data set of international book building allocations and find that the underwriter favors both regular investors and investors that supply information on the value of the issue. Jenkinson and Jones (2002) analyze a different sample of European bookbuilds, finding (among other things) that large and early orders are favored over smaller and later orders. I would argue that free riders are more likely to place orders later in the process, after they have observed the demand of others (part of a Welch (1992) cascade?), and that investors that have better information and are more sure of their valuation would tend to place larger orders, as shown in Chowdhry and Sherman (1996b).

Ljungqvist, Jenkinson and Wilhelm (2000) compare data on book building and public offer IPOs for a large number of countries. They find that book building is substantially more expensive than public offer and that it does not, by itself, reduce underpricing. However, book

10 The trade-off in the Chemmanur and Liu model does not apply to book building because the central aspect of book building is the gathering of market feedback before setting the price, in order to incorporate the responses into the price. Moreover, the disadvantage they identify doesn't apply uniformly to all fixed price methods. Chowdhry and Sherman (1996a) show that the common practice of collecting payment in advance, allowing the issuer to keep the float on subscription funds, allows the issuer to earn at least some benefit from higher market demand for shares. For best efforts offerings in the U.S., Sherman (1992) demonstrates that, even though the price is set before market feedback is obtained, issuers can raise greater proceeds when demand is higher because the number of shares adjusts. Nevertheless, Chemmanur and Liu offer an explanation for the fact that public offer (i.e. fixed price) methods have repeatedly been chosen over auctions, a somewhat puzzling phenomenon that has not been explained by other work. Hopefully, future empirical work on Taiwanese, Singaporean or other data will

building leads to lower underpricing when conducted by U.S. banks and/or targeted at U.S. investors and, for "the great majority of issuers, the gains associated with lower underpricing outweigh(s) the additional costs associated with hiring U.S. banks or marketing in the U.S."[11]

3. The Model

To compare book building to auctions, I first define what qualifies as an auction. The term "auction" is used loosely in a variety of settings that involve some sort of feedback ("bids") on the value of the auctioned object(s), and published research on auctions seldom, if ever, gives a general definition. The key distinction between book building and auctions is that, with book building, the underwriter can refuse any order for any arbitrary reason. With auctions, the auctioneer is expected to follow pre-set rules and is not allowed to allocate based on past personal relationships. Therefore, the definition of an auction in this paper is that allocations are determined solely by bids[12]. In other words, any two bidders that place the same bids are expected to receive the same allocations.

I analyze both book building and auctions for the same environment. The auctions are multi-unit, common value auctions with endogenous entry and information acquisition. Both discriminatory (pay what you bid) and uniform price auctions are modeled. The book building model extends previous work by characterizing the optimal solution when the issuer is allowed to price-discriminate, and by endogenizing the accuracy level of individual investors' signals. Investors choose the amount of time and attention to devote to scrutinizing the firm, knowing that greater attention tends to lead to greater accuracy. The issuer selects both the number of investors that will be allowed to participate and the accuracy of each investors' information, setting prices and allocations in order to induce investors to purchase the optimal amount of information.

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show whether they have identified the most relevant factors in that choice.

[11] There are many other excellent IPO papers that unfortunately are not elsewhere mentioned here, including Loughran and Ritter (2002), Habib and Ljungqvist (2001), Schultz (2001), Pichler and Wilhelm (2001), Ljungqvist and Wilhelm (2001), Maksimovic and Pichler (2001a, 2001b), Busaba (2000), Subrahmanyam and Titman (1999), Spatt and Srivastava (1991), Welch (1992), Chemmanur (1993), Chemmanur and Fulghieri (1994), Kim and Ritter (1999), Dunbar (2000), Derrien and Womack (1999), Goergen (1998), Camp and Munro (2000), Arosio, Guidici and Palear (2000), Beierlein (2000), and Dewenter and Field (2001). For a very good survey of U.S. IPO papers, see Ritter and Welch (2002).

[12] Parlour and Rajan (2002) take the opposite approach, using the term auction in a broader sense that includes book building, public offer, best efforts and other IPO methods as subsets or types of auctions. While this is a reasonable approach, it leads to the problem of what term to use for "traditional" auctions.

3.1 The environment

The environment is the same for both models. The issuer requires a fixed amount of capital and plans to sell a fixed number of shares, X. If it raises more than is needed, any excess will be paid to the original shareholders. The issuer is risk neutral and maximizes the expected proceeds minus f(P(·,0)), a term which reflects the possibility of price inaccuracy. In other words, the issuer prefers higher to lower expected proceeds, but also prefers a more accurate valuation of the issue[13]. P(·,0) is the probability that the true state is not discovered. I assume that f(P(·,0)) > 0 for all P(·,0) ∈ {0, 1}, f'( ) > 0, f''( ) < 0, f(0) = 0 and f(1) is sufficiently large, relative to the cost of the information (C(α)), that the underwriter will always choose to induce investors to purchase at least some information.

There are two dates. The market price at date two, the initial trading date, reflects the true state, high (h) or low (ℓ). On date two, the value per share given state j, j ∈ {h, ℓ}, is s^j. For simplicity and without loss of generality, $s^h = 1$ and $s^\ell = 0$. State h occurs with probability θ. Thus, the expected value per share is $s^m = \theta\, s^h + (1 - \theta)\, s^\ell = \theta$.

There are N investors with access to both capital and information ("informed investors"). They must purchase their information, paying C(α) dollars for a signal that has probability α of revealing the true state (H if h or L if ℓ). With probability 1 - α the investor receives a neutral signal (M). There is zero probability that the investor gets a false high or low signal (H if ℓ or L if h).[14] C(α) is twice differentiable, strictly increasing and strictly convex for α ∈ (0, 1), and C(0) = 0. Assume N > X, so it is possible for informed investors to purchase the entire issue. There is also a plentiful supply of uninformed investors (investors that are unable to purchase information, or at least cannot obtain information at a competitive price).

All investors have an alternative investment with an expected net rate of return of r, which to simplify notation is set equal to 0. Investors that wish to participate in the IPO must

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[13] Reasons why the issuer might prefer more accurate valuation are discussed briefly in the introduction. Moreover, I show that the extra flexibility of book building benefits even an issuer that does not value greater price accuracy, since the flexibility can be used to minimize underpricing.

[14] High or low signals may be interpreted as the detection of favorable or unfavorable information on the market value of a firm that was not discovered by the underwriter. I assume that information known by the firm and/or the underwriter has already been signaled to investors. In practice, of course, a high quality issuer may still have some information that it cannot convey credibly and cheaply through the prospectus and through road shows, and thus the choice of offering method may signal quality.

pay a fixed entry cost $e > 0$, which can be thought of as a dead weight "bid preparation" cost or as a fixed cost of evaluation.

The unconditional probabilities of state h occurring and of none of the K informed investors receiving signals H or L are $P(h,0) = \theta\,(1 - \alpha)^K$ and $P(\ell,0) = (1-\theta)\,(1 - \alpha)^K$. The unconditional probability that none of the K investors receive informative signals is $P(\cdot,0) = P(h,0) + P(\ell,0) = (1 - \alpha)^K$. The conditional probability that 0 of the K-1 other investors will receive an H or L signal is $P'(h,0) = P'(\ell,0) = P'(\cdot,0) = (1 - \alpha)^{K-1}$. The unconditional probability of state h occurring and of k of the K informed investors receiving signal H is:

$$P(h, k) = \theta \binom{K}{k} \alpha^k (1 - \alpha)^{K-k}$$

Similarly, P(entry = i) is the probability that i of N potential auction bidders will choose to enter the auction (given that the probability of entry by each individual is p):

$$P(\text{entry} = i) = \binom{N}{i} p^i (1 - p)^{N-i}$$

3.2 The book building solution

To match the essential feature of book building, I assume that the underwriter controls the allocation of shares. The underwriter can and will communicate with shareholders before setting the issue price, choosing an allocation and pricing scheme that gives investors an incentive to purchase and report the desired amount of information. I do not impose a one price rule - the underwriter can and will charge different prices to different investors.

I assume that there are no conflicts of interest between the underwriter, who will be pricing and marketing the issue, and the entrepreneur/issuer. Both prefer a high issue price but also value price accuracy. Biais, Bossaerts and Rochet (1998) examine the other extreme, assuming that the underwriter colludes with informed investors against the issuer.

To distribute and price the issue, the underwriter enlists the help of K risk neutral informed investors, where K is chosen by the underwriter. The underwriter also prices the issue and decides how many shares to allocate to each investor. The allocation to each investor may depend on both the signal reported by that particular investor and the signals reported by other investors (i.e. on k, the number of investors out of K that report either H or L).

Informed investors may report H, L or M ("neutral"), while the uninformed "report" only U (a notational convenience to minimize the amount of separate terms introduced, since the underwriter may select different prices and allocations for informed investors reporting informative signals, informed investors reporting neutral signals, and uninformed investors). The following notation is for all $i \in \{H, L, M, U\}$, $j \in \{H, M\}$, $t \in \{M, U\}$:

$s_{i,j,k}$ = issue price to an investor that reports i when j is reported by k of K informed investors;
$q_{i,j,k}$ = allocation to an investor that reports i when j is reported by k of K informed investors;
$s_{t,M}$ = issue price to an investor that reports t when all informed investors report M; and
$q_{t,M}$ = allocation to an investor that reports t when all informed investors report M.

At date 1, the underwriter announces the price and allocation schedule and selects the informed investors who will be allowed to participate in the offering. Those investors then decide whether to purchase a signal and whether to reveal that signal to the underwriter. Next, the underwriter sets the offering prices and allocations, based on the information provided by informed investors. Any shares not allocated to informed investors may be sold to uninformed investors. At date 2 the shares begin trading and the true value per share is revealed. Below is a summary of the timing in this model.

Date 1 Underwriter selects informed investors, announces price & allocation schedule	Informed investors select accuracy, purchase information	Informed investors report signals to underwriter	Underwriter sets prices, allocates shares (based on announced schedule)	**Date 2** Shares begin trading; value revealed

3.2.a Information reporting constraints

As part of its book building strategy, the underwriter must design an allocation and pricing schedule that elicits accurate information from investors. Since the investment bank will use the reported information to price the issue, the pricing and allocation strategy must counteract investor incentives to withhold favorable information that will lead to a higher issue price. I consider Nash equilibria where, conditioned on the underwriter's strategy, investors

have an incentive to truthfully reveal their information, given their expectation that other investors will also report information accurately.

There will typically be multiple solutions to the underwriter's problem, with many sets of allocations and prices that elicit truthful revelation and give both the underwriter and investors the same expected utility. To eliminate these extraneous equilibria, I assume without loss of generality that all investors that report the same signal receive the same allocation. I also assume that the underwriter allocates zero shares to all investors who reveal conflicting signals. Although such conflicting reports will not exist within the equilibrium, this out-of-equilibrium assumption is needed to fully specify the equilibrium.

Let $R_B(j,i)$ be the expected profit to an informed investor who receives signal j and reports signal i (under the book building system). In equilibrium, informed investors are induced to report their information truthfully, which implies that the following truth-telling constraints (described in more detail in Appendix A) must be satisfied[15]:

$$R_B(j, j) \geq R_B(j, i) \text{ for all } j, i \in \{H, M, L\} \tag{1}$$

3.2.b Participation and information collection constraints

In addition to the truth-telling conditions, constraints are needed to guarantee that informed investors choose to participate and to acquire information. The binding constraint[16] is that buying and reporting a signal offers a higher expected profit than not purchasing a signal and falsely reporting M:

$$\alpha\, \theta\, R_B(H,H) + \alpha\, (1\text{-}\theta)\, R_B(L,L) + (1\text{-}\alpha)\, R_B(M,M) - C(\alpha) - e \;\geq\; R_B(M,M).$$

This participation constraint (PC) for book building can be re-written as

[15] Note that the cost of acquiring information does not affect the information reporting conditions, since it is a sunk cost by the time the investor decides what signal to report. On the other hand, whether or not the investor plans to accurately report information certainly affects the incentive to purchase a signal. After all, if the investor planned to report M (or H or L) regardless of the actual signal, then there would be no reason to buy a signal.

[16] In addition, buying a signal and reporting it must be at least as good as saving the costs e and $C(\alpha)$, and either falsely reporting H or L, or not participating at all. As long as the truth-telling constraints are satisfied, however, the return to falsely reporting H or L will never be higher than the return to falsely reporting M. This solution is based on the interpretation of e as a fixed cost of information, rather than as an entry fee. The issuer would have even more flexibility if e was interpreted as an entry fee, since this would allow the issuer to use the entry fee to prevent free riders.

$$PC_B \quad = \quad \theta \sum_{k=1}^{K-1} P'(h,k)[(s^h - s_{H,H,k+1})q_{H,H,k+1} - (s^h - s_{M,H,k})q_{M,H,k}]$$

$$+ \theta P'(h,0)[(s^h - s_{H,H,1})q_{H,H,1} - (s^m - s_{M,M})q_{M,M}] + (1-\theta)\, P'(\ell,0)\, [(s^\ell - s_{L,L,1})q_{L,L,1} - (s^m - s_{M,M})q_{M,M}]$$

$$+ (1-\theta) \sum_{k=1}^{K-1} P'(\ell,k)\, [(s^\ell - s_{L,L,k+1})q_{L,L,k+1} - (s^\ell - s_{M,L,k})q_{M,L,k}] - (1/\alpha)\,(C(\alpha) + e) \geq 0 \qquad (2)$$

In addition, to guarantee that the choice of alpha is optimal for the informed investor, the derivative of the participation constraint with respect to α must equal zero. In other words, the following first order condition must be satisfied with equality for $0 < \alpha < 1$:

$$FOC_B \quad = \quad \theta \sum_{k=1}^{K-1} P'(h,k)[(s^h - s_{H,H,k+1})q_{H,H,k+1} - (s^h - s_{M,H,k})q_{M,H,k}]$$

$$+ \theta P'(h,0)[(s^h - s_{H,H,1})q_{H,H,1} - (s^m - s_{M,M})q_{M,M}] + (1-\theta)\, P'(\ell,0)\, [(s^\ell - s_{L,L,1})q_{L,L,1} - (s^m - s_{M,M})q_{M,M}]$$

$$+ (1-\theta) \sum_{k=1}^{K-1} P'(\ell,k)\, [(s^\ell - s_{L,L,k+1})q_{L,L,k+1} - (s^\ell - s_{M,L,k})q_{M,L,k}] - C'(\alpha) \geq 0 \qquad (3)$$

The second order condition is satisfied, since $C(\alpha)$ is convex.

Next, uninformed investors must have an incentive to participate. Uninformed investors face no participation costs, so they will be willing to purchase shares unless the shares are overpriced, which leads to the following set of constraints:

$$s_{U,j,k} \leq s^j \text{ and } s_{U,M} \leq s^m \text{ for all } j \in \{H, L\}, k \in \{1,2,..,K\} \qquad (4)$$

Last, informed investors will not participate, once the state is revealed, if the shares are overpriced. This provides a final set of investor constraints:

$$s_{i,j,k} \leq s^j \text{ and } s_{M,M} \leq s^m \text{ for all } j \in \{H, L\}, i \in \{H, M, L\}, k \in \{1,2,..,K\} \qquad (5)$$

3.2.c The Underwriter's Objective

As already described, the issuer/underwriter prefers higher to lower expected proceeds but also places some value on the accuracy of the issue price. The underwriter has a very large number of choice variables in this model, making presentation of the full optimization problem messy. However, some of the choice variables can be determined by substituting in from the constraints already presented, thus greatly simplifying the maximization problem of the underwriter. The following proposition details basic features of the equilibrium solution:

Proposition 1: The book building equilibrium will be such that:

1) $s_{U,j,k} = s^j$ and $s_{U,M} = s^m$ for all $j \in \{H, L\}$, $k \in \{1,2,..K\}$;

2) $s_{j,L,k} = s^{\ell}$ for all $j \in \{L, M\}$, $k \in \{1,2,..K\}$;

3) $s_{M,H,k} = s^h$ and $s_{M,M} = s^m$ for all $k \in \{1,2,..K\}$

In other words, the underwriter will not underprice shares 1) to uninformed investors; 2) when state L is revealed; or 3) to informed investors that report a neutral signal (M). Thus, shares will be underpriced only to informed investors that report signal H.

Proof: See Appendix B.

Given these features of the equilibrium, the underwriter's remaining choice variables are K, α, and the prices and allocations for informed investors that report a good signal. These variables are chosen to maximize a utility function that is a separable function of the accuracy of the initial aftermarket price and the expected proceeds of the issue. In particular, the underwriter chooses K, the number of investors invited to participate in the offering, and α, the accuracy of each informed investor's signal, by trading off the increase in accuracy associated with a larger number of more accurate signals against a corresponding increase in the required underpricing to compensate investors for their evaluation costs. The underwriter's maximization problem is:

$$\max_{\substack{K,\ \alpha,\\ s_{H,H,k} \text{ and } q_{H,H,k}\\ \text{for } k \in \{1,2,..,K\}}} \quad X\theta - K \sum_{k=1}^{N} P(h,k))\,(s^h - s_{H,H,k})\, q_{H,H,k} - f(P(\cdot,0))$$

Subject to equations (1), (2), (3), (4), (5), and the restrictions that prices and allocations cannot be negative and that exactly X shares are sold.

3.3 The auction models

In this section I will determine the bidding strategies and entry probability in two multi-unit, sealed bid auctions - a uniform price and a discriminatory auction - given the environment described in section 3.1. For simplicity, I assume that shares are allocated to bidders even if the number of bids is less than X, the available number of shares, and that each bidder can only bid for one share. The lowest acceptable bid price for either auction is equal to the lowest possible

value, which in this case is zero. This can be thought of as the reservation price for the auction[17]. For the X+1[st] price auction, if there are less than X+1 bids, all bidders will pay the "reservation price" - the value of type L shares.

Limiting bidders to one share each may affect the equilibrium, and thus the comparison between the two types of auctions. The argument in favor of uniform price auctions is often based on the comparison between first price and second price auctions. In a first price common value auction, participants have an incentive to shave their bids to adjust for the winner's curse, but it is a dominant strategy to bid one's full valuation in a second price auction. Ausubel and Cramtom (1998b) have shown that this reasoning extends to multi-unit settings only if bidders are limited to one unit each. With multiple bids, bidders may shave the price bid on subsequent units because each subsequent bid may lower the market-clearing price (and thus the price paid on all units). In IPO auctions, however, the large number of bidders makes this effect negligible, since there are likely to be dozens, perhaps hundreds, of bids at the market clearing price.

Similarly, the likelihood of collusion may change when multiple bids are allowed (Back and Zender, 1993), but this risk is also reduced by the fact that there are thousands of expected bidders and millions of potential bidders. Last, the choice of uniform price vs. discriminatory auction may affect the number of units for which people would like to bid (Tenorio, 1997).

In this model, both the number of bidders and the precision of each bidder's information is endogenous. Each potential bidder chooses p, the probability that the bidder will choose to enter the auction, and α, the accuracy of the information purchased. There are N potential bidders for the X available shares. The timing is as follows:

Date 1				**Date 2**
N potential bidders choose p, probability of entering auction	Entering bidders purchase signal of accuracy α	Bidders observe signals, pay e, place bids	Shares are allocated to the X highest bidders	Shares begin trading; value revealed

[17] This reservation price has not been optimally selected by the issuer. It is the lowest reservation price that the issuer might choose, since all shares can always be sold at this value. I leave it to future research to examine the optimal reservation price in a multi-unit auction with endogenous entry and information acquisition.

I do not specify the issuer's maximization problem for the auction because, although the issuer has the same preferences as with book building, it does not have any choice variables. The rules of the auction do not allow the issuer to choose either the issue price or individual allocations. It's possible that the issuer could adjust e, N or the type of auction (discriminatory vs. uniform price sealed bid, or more interactive online auctions such as those in Australia) to affect the outcome, although such discretion would be greatly limited in most countries.

Before the auction begins, bidders choose the symmetric equilibrium pair (p, α) (for sufficiently large N) to satisfy the following participation constraint

$$PC_A = \alpha\,\theta\,R_A(b|H) + (1-\alpha)\,R_A(b|M) - C(\alpha) - e = 0, \quad \text{for } A \in (D, U)$$

where PC_A is the expected profit of a bidder who enters the auction with probability p and, on entering, acquires information of accuracy α; $R_A(b|H)$ is the expected profit given that the bidder enters, purchases a signal and observes H, and $R_A(b|M)$ is the expected profit given that the bidder enters, purchases a signal and observes M. This general equation is the equivalent of (2) above for the book building method, and it applies to both types of auctions (although, of course, the expected profit formulas will depend on the type of auction).

For $p < 1$, the above equation must be satisfied with equality, so that potential bidders are indifferent, ex ante, about whether or not they participate. If N is not large enough, the participation constraint may be strictly positive and $p = 1$. In other words, for a sufficiently small N, the auction can profitably accommodate all bidders, leading potential bidders to enter with probability one. Since the goal of most IPO auctions is to open up bidding to "everyone", I will focus on the case where N is large enough that the optimal p is less than one.

The following first order condition (FOC) for α, the accuracy of the information purchased, must also be satisfied:

$$FOC_A = \theta\,R_A(b|H) - R_A(b|M) - C'(\alpha) = 0, \quad \text{for } A \in (D, U)$$

where FOC_A is the derivative of the bidder's participation constraint with respect to that bidder's choice of α, given the choices of other bidders. The second order condition is satisfied, since $C(\alpha)$ is convex.

Given that the above first order condition must hold, we can use it to simplify the participation constraint:

$$PC_A' = \alpha C'(\alpha) + R_A(b|M) - C(\alpha) - e = 0$$

The solution to the auction is as follows.

Proposition 2: In the first stage of the auction, potential bidders decide whether or not to enter, and they choose their information accuracy. They select α and p to uniquely solve $PC_A = 0$ and $FOC_A = 0$.

In the second stage of the auction, the bidding, bidders that receive the signal L do not bid, those with signal M draw a bid from the cumulative bidding distribution $M_A(b;\alpha,p)$, for $b \in (\underline{m}_A, \overline{m}_A)$, and bidders that observe signal H draw a bid from $H_A(b;\alpha,p)$, for $b \in (\underline{h}_A, \overline{h}_A)$.

Proof: See Appendix C.

The cumulative bidding distributions are given in Appendix C, along with the limits to the bidding ranges for each auction type. Bidders bid in distinct intervals in both auctions. Those that receive a low signal do not bid, while those that receive a neutral signal will randomize over a range from $\underline{m}_A$ to $\overline{m}_A$. Those that receive a high signal will randomize over the interval from $\underline{h}_A$ to $\overline{h}_A$.

For the discriminatory auction, the upper limits of the optimal bidding ranges for investors that receive either an M or H signal are always strictly less than the expected values given those signals, and thus the auction leads to underpricing. For the uniform price auction, bidders that observe H bid the full value, and thus there is the possibility of zero underpricing if at least X+1 bidders observe a high signal.

The following are the (simplified) participation constraints and first order conditions for the uniform price auction (U) and the discriminatory auction (D).. P(undersubscription) is defined in Appendix C.

$$PC_U' = \alpha C'(\alpha) + \theta\, P(\text{undersubscription}) - C(\alpha) - e = 0$$

$$FOC_U = \theta \int_{\underline{m}}^{\overline{m}} (1 - z)\, f^{H}(z)\, dz - C'(\alpha) = 0$$

$$PC_D' = \alpha C'(\alpha) + \theta\, (1-p)^{N-X} - C(\alpha) - e = 0$$

$$FOC_D = \theta (1 - p\alpha)^{N-X} \frac{1 - \theta + \theta (1 - p))^{N-X}}{1 - \theta + \theta (1 - p\alpha)^{N-X}} - \theta (1-p)^{N-X} - C'(\alpha) = 0$$

The bidders' ex ante expected profits are zero in both auctions. Even though the cost of information is a sunk cost by the time the bidder submits his bid in stage 2, the choice of the entry probability p in stage 1 depends on information costs. The expected number of bidders entering the auction will be sufficiently low for the bidders to recover their cost of evaluation. The seller ends up indirectly paying for the evaluations of the investors through a lower expected selling price.

3.4 Comparison of the book building and auction solutions

Both the book building and the auction equilibria involve underpricing. The following proposition lays out the expected proceeds under each method.

Proposition 3: The book building and auction solutions will result in the following expected proceeds or "seller's expected revenue", SER_B for book building and SER_A for either type of auction:

$$SER_B = \theta X - K [C(\alpha) + e] \tag{6}$$

$$SER_A = \theta X \left(1 - \sum_{i=0}^{X-1} P(\text{entry} = i) \left(1 - \frac{i}{X} \right) \right) - p N [C(\alpha) + e] \tag{7}$$

Proof: See Appendix D.

A comparison of equations (6) and (7) demonstrates the similarities and differences of the two methods. For both, the expected value of the shares for sale is θX (X shares worth, on average, θ each). Both SERs are reduced by the last term, the expected information expenditures of $C(\alpha) + e$ per investor. The information costs vary both through α, which is chosen endogenously, and through the expected number of investors. For book building, the underwriter selects K investors. For the auction, the expected number of bidders is equal to N, the number of potential investors, times p, the equilibrium probability of entry of each bidder. In addition, the first term of SER_A is more complicated than the θX from SER_B, because it is possible that fewer than X shares will be sold. Thus, the auction expected proceeds are lowered by the probability of undersubscription.

In other words, for all three methods the expected proceeds are equal to the expected value of the shares sold, minus the expected information costs of the investors. In this sense, the book building and auction solutions at first seem to be equivalent, but there are two key differences: 1) the greater ability to control information expenditures, and thus control expected proceeds, with book building; and 2) the possibility of undersubscription in the auction, which strictly lowers expected proceeds.

I illustrate these differences through a simple numerical example. Consider two otherwise identical issuers that differ only in their relative preferences for greater accuracy vs. a higher expected issue price[18]. In other words, the two issuers have two different functions for $f(P(\cdot,0))$, the value of information. Let $\theta = 0.5$, $C(\alpha) = 0.5\alpha^5$, $e = 0.015$, $X = 3$ and $N = 7$. The preferences for price accuracy are: $f(P(\cdot,0)) = 0.1\ (P(\cdot,0))^{0.5}$ for Issuer 1, who has only a slight preference for more information and $f(P(\cdot,0)) = 1.0\ (P(\cdot,0))^{0.5}$ for Issuer 2, who has a stronger preference for price accuracy in the aftermarket.

The solution to this example is shown in Table 1, below. The underpricing[19] shown is the amount needed to compensate investors for their cost of information, as a percentage of the expected value of all shares being offered (i.e. without adjusting for undersubscription)[20]. The "information level" = $1 - P(\cdot,0)$ = the probability that the true state is revealed.

Table 1. Initial Returns and Information Acquisition for the Three IPO Methods

	Issuer 1		Issuer 2	
	Underpricing	Information Level	Underpricing	Information Level
Book building	3.9%	75.7%	9.6%	96.3%
Uniform price auction	5.7%	68.0%	5.7%	68.0%
Discriminatory auction	4.6%	80.1%	4.6%	80.1%

Investors do not receive excess returns under any of the methods. In that sense, auctions are fairly efficient and may, in some cases, give the issuer a near-optimal solution (ignoring the risk of undersubscription). However, this occurs only by chance. If the outcome

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18 Readers skeptical of the idea that issuers might value anything other than the highest possible expected proceeds may choose to focus only on the solution for the issuer that puts very little weight on price accuracy.

19 The amount shown is actually the initial return – the expected return that an investor would expect from buying at the offering price and selling on the aftermarket. This measure, using the offering price in the denominator, leads to a more skewed distribution, emphasizing large initial returns. A better measure of the amount "left on the table" is to use the aftermarket price in the denominator. Nevertheless, I have chosen to use the more common measure, which reflects returns to investors rather than discount to the issuer.

20 In other words, the expected initial return for the auction will be strictly greater than the amount shown, because the expected number of shares sold is less than X, due to the possibility of undersubscription. I present

does not match the issuer's preferences, the issuer has little alternative. The primary point of Table 1 is that the auction solutions are the same, regardless of the issuer's preferences, because the issuer/underwriter cannot select the outcome.

In this case, the uniform price auction for both issuers involves expected underpricing of 5.7% and a 68% probability that the true value of the project will be revealed, while the discriminatory auction leads to less underpricing, only 4.6%, and more information, an 80.1% chance that the true value is revealed. With book building, however, the underwriter can match the information-gathering preferences of each issuer, offering 3.9% underpricing and a 78% information level to the issuer that is primarily concerned with a high issue price, and 9.6% underpricing and a 96% information level to the issuer with a stronger preference for price accuracy. Note that, even if an issuer does not value price accuracy and cares only about maximizing the issue price, the flexibility of book building is valuable because it allows the underwriter to minimize underpricing.

The second key difference between the methods is that auctions are riskier. With book building, there is no risk that the issue will fail due to lack of scrutiny, since the underwriter will recruit a sufficient number of investors who will each have an incentive to attend the road show and consider the offering[21]. Book building can be seen in part as a co-ordination mechanism to ensure entry of the optimal number of participants. With auctions, the *expected* number of bidders may be optimal, but ex post there is still a chance that too few bidders will show up, and the auction will be undersubscribed.[22]

The results in Table 1 make it appear that the discriminatory auction is strictly superior to uniform price in terms of the underpricing/information trade-off, offering both less underpricing and more information collection. However, this reflects only the underpricing due to the costs of information collection, assuming that all shares are sold. Since all shares are not

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the numbers in this way to try to separate out the two effects. The actual underpricing level is given later.

[21] There is a risk, with either book building or an auction, that the shares will be revealed to have low value and will be priced accordingly. This means that book building IPOs may "fail" in the sense that the issuer may decide that the price guaranteed by the underwriter is too low and may withdraw the issue. Benveniste, Busaba and Guo (2000) show that about 14% of U.S. IPOs were withdrawn or postponed in 1989-94. In the U.S., firm commitment IPOs are also sometimes converted to best efforts IPOs because the underwriter will not guarantee a sufficiently high price at the final pricing meeting, and the entrepreneur prefers to take his chance on the market, rather than lock in a low price or give up altogether.

[22] In practice, many countries require IPOs to be fully or partially underwritten (meaning that the underwriter guarantees the proceeds), regardless of the issue method - book building, auction or public offer. With auctions, underwriting usually means guaranteeing the purchase of all shares at the minimum or reservation price. Thus, the issuer can often insure against losses due to undersubscription, but this does not eliminate the cost, it only evens

expected to be sold in the auctions, the shares that are expected to be sold must be discounted enough to cover the full information costs. The total underpricing for the auctions will be 6.1% for uniform price and 37.8% for discriminatory.

The reason that total expected underpricing is so much higher for the discriminatory auction can be seen in Table 2. The probability that the number of bids will be strictly less than the number of shares available is 46.7% for the discriminatory auction and only 5.5% for the uniform price auction. For book building, the underwriter selects K and thus ensures that a sufficient number of investors evaluate the shares (although they may not like what they see). With the auctions, each of the 7 bidders decides for him- or herself whether to enter. The expected number of bidders is 5.4 for the uniform price auction and 2.7 for the discriminatory auction, but there is a positive probability that none (or all) of the potential bidders will enter, regardless of the quality of the issue.

Table 2. SER and Risk for the Three IPO Methods

	Seller's expected proceeds (SER)	Probability of undersubscription	Expected number of auction bidders
Book building, low info.	1.44	0.0%	N.A.
Book building, high info.	1.37	0.0%	N.A.
Uniform price auction	1.41	5.5%	5.4
Discriminatory auction	1.09	46.7%	2.7

The usual way for auctions to be compared is based on seller's expected revenue (SER). On this basis, Table 2 shows that book building can offer the issuer higher expected proceeds than either auction. An issuer with a strong preference for information may end up with a lower SER from book building than from an auction, but this would be by choice, in order to get more information. The possibility of undersubscription lowers the issuer's expected proceeds, holding information expenditures constant, as discussed in the following proposition.

Proposition 4: Holding expected evaluation costs constant, $SER_B > SER_A$ for either auction type.

Proof: See Appendix E.

out the distribution of that cost.

Thus, the extra uncertainty of auctions leads to lower expected utility even for a risk neutral issuer. If issuers or investors are risk averse, auctions are at an even greater disadvantage. The risk to investors in an auction comes from the fact that they must each decide whether or not to enter and how much information to purchase without knowing whether or not they will receive shares. Each potential bidder thus factors in the probability that, *ex post*, either too few bidders will enter and the auction will fail, or too many bidders will enter and bid away all potential profits (see Levin and Smith, 1994). In either of these cases, the bidder may end up paying to evaluate the issue, only to receive nothing.

3.5 Comparison of the two auction solutions

Vickrey's (1961) famous paper showed that first price, second price, English and Dutch auctions all raise the same expected proceeds in a single-unit, private values setting. The ranking of second price over first price auctions with affiliated values goes back to Milgrom and Weber (1982), who showed that the Vickrey revenue equivalence results for private values do not hold with affiliated values. For single unit common value auctions with endogenous entry, both Harstad (1990) and Hausch and Li (1993) showed that, in their models, the SER of the second price auction was at least as great as the SER of the first price auction[23].

The ranking of second price over first price auctions in Harstad and in Hausch and Li is driven by their result that p, the probability of entry, is always at least as high for the first price as for the second price auction. Harstad does not allow bidders to choose the quality of their information, but Hausch and Li also find that α, the quality of the information purchased, is at least as high for the first price as for the second price auction. Higher p and α result in higher information costs and thus lower expected proceeds in the auction. Both papers rank second price over first price auctions because the second price auction leads to less information collection, although it also leads to a higher probability that the auction will fail.

Unfortunately, the multiple unit auctions in this paper are too complicated to compare analytically, in order to derive an overall ranking[24]. The numerical example is sufficient, however, to show that the results of Harstad and of Hausch and Li on the probability of entry,

[23] Harstad also showed that publicly announcing any information that the seller has cannot lower, and may raise, expected proceeds, and that higher entry fees and correspondingly lower reserve prices generally raise SER.

[24] In particular, the choices of p and α in the uniform price auction depend on the chance that a particular price, Z, will be the X+1[st] bid. As can be seen from the formulas in Appendix C, the terms are especially messy and very different from those for the discriminatory auction solution.

p, do not hold for the multi-unit case[25]. The p, α pairs for the discriminatory and uniform price auction are (.38, .46) and (.77, .19) respectively. In this example, and in every other example I tried, the value for p in the uniform price auction is strictly higher than in the discriminatory auction.

Just this one counterexample proves that the Harstad/Hausch and Li results on p do not hold for the multi-unit case. However, I experimented extensively to find an example where the value of p was strictly lower, or even equal, for the uniform price auction. I could not find even one set of entry probabilities that was consistent with earlier single-unit auction results, although the values got close as both converged to a corner solution. In every example, p was strictly higher and α was strictly lower for the uniform price auction.

Although my ranking of entry probabilities for the two auctions does not match those of either Harstad or Hausch and Li for the single unit case, it appears, based on extensive experimentation, that the overall ranking of SER is the same for the multi-unit as for the single unit case. In all of my numerical simulations, information gathering costs were lower and thus seller's expected proceeds were higher for the uniform price auction, relative to the discriminatory auction. In other words, my overall results appear to be consistent with the rankings of Milgrom and Weber, Harstad, and Hausch and Li, since in every example, $SER_U > SER_D$. If issuers care only about maximizing expected proceeds, then it appears that all issuers should prefer a uniform price to a discriminatory auction.

Table 3 shows the bidding ranges for the two auctions in my example. The upper limit on bids in the discriminatory auction, for bidders that observe signal H and thus know that the shares are worth one, is 0.634, which would lead to a 58% initial return. For bidders at the lower end of the informed range, the initial return will be 360% (because they pay 0.217 for something they know is worth 1.0). Bidders that observe a neutral signal and bid at the top of their range have a 50% chance (ex ante) of a 360% return and a 50% chance of a 100% loss. Conditional on having a winning bid, their chance of a 360% return would be much lower than 50%, of course (due to the winner's curse).

[25] It should be noted that a uniform, X + 1st price auction is not the closest multi-unit generalization of a Vickrey second price auction, which may explain why the results are not the same. See Ausubel and Cramton (1998a).

Table 3. Bidding Ranges for the Two Auctions

	Discriminatory	Uniform price
Bidding range given signal M (expected value = 0.5)	0 to 0.217	0.260 to 1.0
Bidding range given signal H (known value = 1.0)	0.217 to 0.634	1.0

For the uniform price auction, all informed bidders in a high value company bid 1.0, the true value. But, for this example, there is only a 1.1% probability that the shares will be priced at their full value, since this only happens when at least X+1 = 4 of the 7 bidders enter and get an informative signal. If the X + 1^{st} bidder received an M signal, then the initial returns for all 3 winning bidders may be up to 284%. Thus it is clear that auctions may lead to substantial uncertainty and underpricing.

3.6 Empirical implications regarding underpricing levels

These results give us some empirical implications on underpricing levels for auctions versus book building. First, because book building offers lower risk for both issuers and investors, it should lead to less underpricing (holding information costs constant), as shown in Proposition 4. The long term relationships modeled in Sherman (2000) also imply that book building will lead to less underpricing, relative to auctions. On the other hand, the flexibility that book building gives issuers, in terms of controlling information expenditure, could lead to either more or less underpricing, depending on the preferences of the issuer.

One implication is that issue methods should not be judged based purely on underpricing levels. A major advantage of book building is that underpricing can be tailored to the preferences of each individual issuer, and can adapt to the circumstances of various countries or time periods. Auctions give issuers little choice – you simply offer up the shares and hope for the best – whereas book building gives issuers and underwriters more control over the process. If issuers choose to use that control to induce higher levels of information collection, and thus higher underpricing, this by itself should not be interpreted as evidence that the issuer is worse off[26].

[26] However, evidence of collusion among underwriters might imply that issuers were being made worse off, since the book building method relies so heavily on the underwriter. For instance, Chen and Ritter (2000) offer evidence that underwriting fees in the U.S. do not respond to competition. This by itself is inconclusive, since underwriters might be competing on other dimensions. There is also evidence that underwriters allocate shares in hot issues to regular investors based on their general relationship, rather than allocating based exclusively on the current issue, or even based exclusively on repeated IPO participation. Again, this by itself is not evidence that issuers are being "cheated", since any side-benefits that an underwriter expects to receive from handling an IPO will be factored into the general package of fees and services that it offers to an issuer.

Suppose a country changes its regulations to switch from auctions to book building, and average underpricing increases after the switch. According to my models, this would be evidence that auctions had previously been leading to inefficiently low levels of information collection and that issuers are now exercising their option to "purchase" more information (through higher levels of underpricing). Both Kutsuna and Smith (2001) and Kaneko and Pettway (2001) examine Japanese IPOs before and after the introduction of book building and conclude that average underpricing was higher under book building than under the hybrid discriminatory auctions that had been used before (although Kutsuna and Smith show that the difference is small after adjusting for skewness and for the 1999 stock market rally).

Kutsuna and Smith also found that, when auctions were required in Japan, some small, high risk but high quality issuers were shut out of the market completely. In addition, they found evidence of greater book building flexibility in the size of issues: "Small issues appear to be more possible under book building, as are issues that are large relative to issuer size" (p. 22). This fits my claim that an auction is a "one size fits all" approach that is not as flexible as book-building in adjusting to suit the needs of a variety of issuers.

4. International Evidence on Choice of IPO methods

This paper identifies some advantages of the book building method, but there are, of course, other advantages and disadvantages to be considered. These include, but are not limited to: 1) the problems of spinning, laddering and other corruption related to IPO share allocations; 2) the effect of the one price rule on book building (this was analyzed in Benveniste and Wilhelm (1990), among others); 3) possible cost differences between the two methods; 4) the "fairness" of certain allocation practices.

Although this model does not capture all "real world" factors at once, it is worthwhile to try to compare its predictions to observed patterns. A key point of my model is that the advantages of book building – greater flexibility, lower risk – do not apply only to certain types of issuers or investors, but to all. I show that the flexibility of book building can be used either to induce more information revelation/underpricing or to induce strictly less, thus appealing to all issuers rather than only to some. Similarly, reducing risk should appeal to all issuers and investors that are even slightly risk averse (and it is hard to imagine that issuers are risk neutral regarding such an expensive, major event). If these advantages are sufficiently large, we would expect to see a corner solution, with book building chosen by most or all issuers.

This is, in fact, the pattern that has occurred around the world over the last decade. Table 4 summarizes the IPO methods used in various countries[27]. By comparing columns, one can see from Table 4 that both book building and public offer are common worldwide, while auctions are rare. Hybrid[28] book building/public offer is perhaps even more popular than "pure" book building. Although Sherman (2000) shows that there is a cost to using hybrid rather than pure book building, underwriters and issuers may feel that it is worth the cost to allow "equal access" for public relations purposes. Bierbaum and Grimm (2002) show that, in some cases, public offer may dominate auctions for the retail tranche of a book building hybrid.

The rarity of IPO auctions is not due to unfamiliarity. Auctions were used in Italy, Portugal, Switzerland and the U.K. in the 1980s, and in Singapore in the 1990s, but were voluntarily abandoned in all of these countries even before book building was introduced. In Japan and France, auctions were used for many years, but they vanished almost immediately in Japan and dried up gradually in France (except on the unregulated over the counter market) once unrestricted book building was allowed. Argentina abandoned auctions for privatization IPOs after a bad experience in 1992. After many years of experimentation, issuers in Taiwan have largely given up on auctions to return to the public offer method.

Israel is the only country that I have been able to find in which auctions are currently the primary IPO method. Book building is not allowed in Israel, so we cannot tell what method issuers would choose if they were given a choice. Hybrid book building/auctions on the exchange have been used in Chile (because of regulations requiring an auction tranche). It is possible that IPO auctions will be used in Peru in the future, even though book building has been gaining popularity there. Because IPO markets in Peru, Chile and throughout South America have been slow for the past few years[29], it is hard to predict whether auctions will re-emerge in that region once the markets recover.

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[27] This table is a summary of the more detailed country information in Appendix F. In Table 4, a blank in any column means that the answer, to the best of my knowledge, is no, the method was/is not used. Note that this table focuses on methods used *within* various countries. Issuers can also list elsewhere, rather than in the domestic market. Ljungqvist, Jenkinson and Wilhelm (2000) examine both international and purely domestic IPOs.

[28] Hybrid offerings, with separate tranches using different methods, are common. There have been hybrid auction/public offer and auction/book building IPOs, but by far the most common combination is book building/public offer. For most hybrids, book building (or sometimes an auction) is used to set the price and to allocate shares to institutional and foreign investors, while a public offer tranche is reserved for local retail investors who do not participate in the price-setting process.

[29] Delistings have greatly outnumbered new listings in Brazil, Argentina and Chile. Chile's last IPO was in 1997.

Table 4. Country patterns in IPO methods

	Book Building			Public Offer		Auction
	Used at least sometimes	**Dominant or gaining popularity**	Hybrid BB/PO used	Used in past	Used today (not incl. hybrids)	Used today
Europe						
Austria	yes	**yes**	yes	yes	?	
Czech Republic				yes	yes	?
Finland	yes	**yes**	yes	yes	yes	
France	yes	**yes**	yes	yes		occasionally
Germany	yes	**yes**	yes	yes		
Hungary	yes	**yes**	yes	yes	yes	
Ireland	yes		yes	yes	yes	
Italy	yes	**yes**	yes	yes		
Netherlands	yes	**yes**	yes	yes		
Norway	yes	**yes**	yes	yes		
Portugal	yes	**yes**	yes	yes	yes	
Spain	yes	**yes**	yes			
Sweden	yes	**yes**	yes	yes	yes	
Switzerland	yes	**yes**	yes	yes		
United Kingdom	yes	**yes**	yes	yes	yes	
N. & S. America						
Argentina	yes	**yes**	yes			
Barbados				yes	yes	
Brazil	yes	**yes**	?	yes	yes	
Canada	yes	**yes**	yes			
Chile	yes	**yes**				hybrid
Mexico	yes			yes	?	
Paraguay				yes	yes	
Peru	yes	**yes**	yes	yes	yes	occasionally
United States	yes	**yes**	yes			occasionally
Asia/Pacific						
Australia	yes	**yes**	yes	yes		
Bangladesh				yes	yes	
China	yes	**yes**	yes	yes	yes	
Hong Kong	yes	**yes**	yes	yes	yes	
India	yes		yes	yes	yes	
Indonesia				yes	yes	
Japan	yes	**yes**	yes			
Korea	yes	**yes**	yes	yes		
Malaysia				yes	yes	
New Zealand	yes	**yes**	yes	yes	yes	
Philippines		**yes**	yes	yes	?	
Singapore	yes		yes	yes	yes	
Sri Lanka				yes	yes	
Taiwan				yes	yes	occasionally
Thailand				yes	yes	
Africa/Middle East						
Kenya				yes	yes	
Israel				yes	yes	yes
Jordan				yes	yes	
South Africa	yes		yes	yes		
Turkey				yes	yes	

In summary, out of more than 40 countries, I have not been able to find even one in which auctions are dominant *even though book building is freely available.* Many types of IPO auction methods have been tried under various market conditions, in both "advanced" and "developing" markets, but virtually all have eventually been abandoned. The absence of IPO auctions today can be more easily explained by familiarity with auction methods than by lack of knowledge about those methods.

A recent exception to the disappearance of IPO auctions is the use of uniform price auctions to sell IPO shares through the internet. W.R. Hambrecht distributed its seventh U.S. IPO through an online auction in May, 2002, while Ord Minnett's eCapital distributed shares in two Australian IPOs through a similar method. Both underwriters used uniform price, sealed bid dirty auctions[30], although eCapital called its process a "book build". In South Korea, several Direct Public Offerings have used internet auctions, although this method cannot legally be used if the company wants to list on the KSE or KOSDAQ.

Why have auctions been so unpopular for new issues? This paper suggests two problems with IPO auctions: that the underwriter cannot control entry to the auction, thus guaranteeing the "right" number of participants, and cannot give an appropriate number of investors an incentive to carefully evaluate the offering. These limitations explain many of the reported problems in past IPO auctions.

Many IPO auction flops have been blamed on either too many or too few bidders entering the auction. Jenkinson and Mayer (1988) report that half (3 out of 6) of U.K. privatization tenders between 1982 and 1987 were undersubscribed, while one was 500% oversubscribed. In 1994, the auction tranche of Sunright, the last IPO auction in Singapore, was 82% undersubscribed (i.e. bids equaled only 18% of available shares), even though the public offer tranche a few days earlier had been oversubscribed. In August of 2000, the

[30] Hambrecht allows dirty auctions, at the discretion of the issuer, but only one issuer has admitted to exercising this option so far. Andover.net was priced on Dec. 7, 1999 at $18 per share, although the market clearing price in the auction was $24. Andover apparently chose to "leave something on the table" only to avoid a delay in completing the IPO. After that offering, WR Hambrecht changed its rules so that investors can no longer tell whether or not an offering is priced at market clearing, and it does not release such information. For Briazz, winning bidders each received only 70% of their orders, while for Overstock.com, winning bidders got only 60%. Thus, either there was an extraordinarily large number of bids at exactly the market clearing price in both cases, or the auctions were "dirty".

Chunghwa Telecom IPO auction in Taiwan was only 72% subscribed, leaving 80.8 million shares unsold[31].

One might guess that the risk of undersubscription would more or less disappear with a large numbers of bidders, due to the "law of large numbers". However, the number of bids must be compared to the number of eligible bidders. For Taiwan's discriminatory IPO auctions, the average number of bidders is around 1,150 (Liu, Wei and Liaw, 2002). More than 16 million adults are eligible to bid in each auction. Therefore, if the participation rate of the eligible population shifts by just seven-one thousandths of one percent in either direction, bids will either almost double or almost vanish[32].

Too many entrants to an auction will not be a problem *if* each of the bidders has carefully evaluated the offering and chosen a reasonable bid price. The auctions in this model demonstrate part of this problem – that the underwriter cannot set allocations and pricing to induce the optimal amount of evaluation by each participant – but my auction models have an entry fee, which allows the issuer to discourage extreme free riders. Since auctions such as the WR Hambrecht "Open IPO" are open to all, including free riders with no clue of the value of the offering, too many entrants can greatly distort the offering price, leading to the overpricing and subsequent first week crash that have been frequently observed in IPO auctions.

Under book building, underwriters devote substantial time and effort to withholding shares from those who will "flip" or "stag" them[33]. Flippers are a problem, not primarily because they are willing to sell shares quickly (after all, the underwriter wants liquidity in the aftermarket), but because they are trying to take advantage of the high average initial returns of IPOs without giving the underwriter anything in exchange. In other words, they are free riders, and much of the investment bank's effort is devoted to weeding them out of the investor pool[34].

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31 One problem with these examples is that there is no way to distinguish between offerings that were undersubscribed because investors scrutinized the offering and didn't like it – a risk for both auctions and book building – and offerings that were undersubscribed because too many investors simply didn't happen to look at the offering – a risk for auctions but not for book building, since the underwriter coordinates the process, making sure that enough investors attend the road show and consider the offering.

32 In addition, large average numbers of bidders will not eliminate the risk of undersubscription if there is some co-ordination, or "leakage" of information, as discussed in Chowdhry and Sherman (1996a).

33 Sherman (2000) shows that underwriters can reduce but not eliminate the excess returns of free riders in a repeated setting.

34 This implies that underwriters will try to prevent unauthorized flipping for hot as well as cold issues. Flipping is sometimes seen as a problem only for cold issues that are receiving price support. However, if the investment banker is trying to prevent some investors from free riding off of the information production of others, he will be more concerned about flipping of hot issues. Ljungqvist, Nanda and Singh (2001) get a similar result in a model through irrationally exuberant "sentiment" investors. See Aggarwal (2000), Boehmer and Fishe (2001) and Fishe

With auctions, especially uniform price auctions, the underwriter has virtually no power to block free riders[35]. If potential investors expect IPO shares to be underpriced, they can avoid the cost of evaluating an issue by simply placing an extremely high bid. In a uniform price auction, this guarantees that they will receive shares at the "market clearing" price from the auction. However, if too many bidders follow this strategy, the shares will be overpriced..

There are many examples of overpricing in uniform price IPO auctions. Jenkinson and Mayer (1988) report that, of 26 mostly uniform price tender offers in the United Kingdom from 1983-1986, the average initial return was –2.2%. Thus, on average the price fell when trading began, in spite of the fact that U.K. tenders often "leave something on the table" by pricing below the market-clearing level. In Singapore in 1994, people joked that IPOs had been struck with "tenderitis" – a tendency for shares sold through uniform price auctions (tenders) to trade below their auction price within their first few days of trading[36].

In Argentina in March 1992, the "disastrous" Telecom privatization was blamed on free riders in the "Dutch" auction system, who "pushed up their price to make sure they would get shares". Many retail investors, upset at losing money on what had seemed like a sure thing, pulled out of the stock market completely, causing a market crash, subsequent extreme volatility and the cancellation of up to 20 other planned equity issues. As a result, Argentina gave up IPO auctions and began using book building for privatizations[37].

While a more detailed investigation of the many specific "IPO auction flops" is left to future research, the pattern is one of inefficient pricing, high aftermarket volatility, and uncertain investor participation. Without the control and flexibility allowed under book building, the underwriter cannot guarantee that a certain minimum number of investors will

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(2001) for more information on flipping in IPOs.

35 The free rider problem is more understandable for uniform price auctions, which might almost have been designed especially to encourage free riding. However, when Japan began allowing book building because of repeated problems with overpricing in their discriminatory auctions, the overpricing problem was blamed on investors who "tend to submit bids much higher than fair value in expectation of steep price rises" (See Jiji Press Ticker Service, August 18, 1997, "'Book Building' Method Eyed for IPOS".

36 "New strategies needed for future IPOs", Ven Sreenivasan, Singapore Straits Times, p. 13, February 3, 1995.

37 "Argentina masters the art of privatization" by Danielle Robinson, *Euromoney,* Jul 1993; p. 24. Argentina had successfully completed several auctions before the Telecom disaster. In fact, it was the positive initial returns in the first few privatizations that convinced average investors that IPO auctions were a free lunch. Note that the risk of major overpricing and thus a dramatic crash may be like the "peso problem" – a low probability event that may not show up except in very large samples, but that deters issuers because the event is sufficiently negative. One could argue that excessive overpricing should be considered positive, from the issuer's standpoint, but issuers in general (as well as underwriters and especially regulators) seem to dislike seeing stock prices plummet during secondary market trading, perhaps for behavioral reasons. The free rider problem may also be path-dependent and thus more likely to show up after several successive IPO auctions result in substantial initial price run-ups.

closely consider the offering, and investors have no guarantee that, if they "do their homework", they'll have a reasonable chance to obtain shares.

5. Conclusion

In the policy debate between book building and auctions, this paper identifies two key advantages to giving issuers and underwriters flexibility in terms of allocating shares. Sherman (2000) identifies a third advantage. These advantages have to be weighed against the potential problems that may arise from giving underwriters so much discretion (i.e. spinning, kickbacks and other possible abuses). Future research may identify more effects, positive or negative, of allocation flexibility, and empirical work may help to pinpoint the relative importance of each. The contribution of this paper is to demonstrate that there are significant advantages to allocation flexibility, and thus that regulators should be cautious about simply banning all underwriter control of allocations, as some have proposed.

Although preferential allocations have always generated controversy because of their perceived problems, the advantages of preferential allocations are significant and have not been widely appreciated. The ability to price offerings more efficiently, and to reduce risk for both issuers and investors, should not be surrendered lightly. These advantages offer an explanation for the observation that, whether the choice is made by issuers or regulators, country after country has rejected the auction method and adopted book building for IPOs.

In this paper, I model book building, a discriminatory auction and an X+1st price auction for the same environment, endogenizing the number of investors and the accuracy of their information. The issuer's expected proceeds under the two methods are similar, except for two key differences: book building carries less risk for both issuers and investors, leading to less underpricing (even under risk neutrality); and it gives issuers more control over information expenditures, and thus more control over underpricing. From a regulatory standpoint, auctions are a subset of book building in which the issuer pre-commits to certain pricing and allocation rules. My comparison illustrates the disadvantages of giving up flexibility in order to pre-commit to auction rules.

This paper contributes to the auction literature by modeling the two types of auctions most used for IPOs in a setting that is appropriate for analyzing small, risky new equity issues. I model two types of sealed bid multi-unit auctions – discriminatory (pay what you bid) and uniform price (X+1st price) auctions – with endogenous entry and information acquisition.

Some of the specific findings of earlier single-unit auctions are contradicted in the multi-unit case, but the overall ranking seems to be the same – that the X+1st price auction offers higher expected proceeds to the seller (SER), relative to the discriminatory auction.

My models predict that, as a country switches from auctions to book building, an increase in underpricing should be interpreted as a sign that the auction method was, on average, leading to too little scrutiny of new issues. The new book building regime should lead to a wider range of intentional underpricing levels, and to a wider range of companies going public. My models do not support the popular belief that auctions should *always* lead to lower expected underpricing, and they predict that issuers will prefer book building to auctions regardless of the direction of the change in underpricing levels.

More research is needed on auctions in a multi-unit, common value setting with costly information and endogenous entry. For instance, do "dirty" auctions (where the issue price is set below market-clearing) provide underwriters with sufficient flexibility, at least under certain circumstances? Biais and Faugeron-Crouzet (2002) and Parlour and Rajan (2002) show that dirty auctions have advantages in a setting with serendipitous (endowed) private information, but these results have not yet been extended to a more general setting in which investors have to expend effort to learn about a new issue. Further analysis of dirty auctions may explain why only one of the first five issuers using the W.R. Hambrecht auction method chose to "leave something on the table".

The French Offre à Prix Minimal is a dirty auction that also has procedures to limit free riding – the highest bids may be thrown out, at the auctioneer's discretion, and the entire auction may be cancelled (with the issuer starting again through a public offer) if demand is "too high". Thus, the unique features of French IPO auctions offer a potential solution to both the winner's curse and the free rider problems. A Vickrey auction might be even more efficient at solving these same problems. Ausubel and Cramton (1998a) show that Vickrey auctions have "important theoretical advantages" over both discriminatory and uniform price auctions, but they involve somewhat complicated pricing formulas[38].

[38] This leads to the more general question of whether the problems with IPO auctions can be fixed, since it seems foolish to simply discard a method that has worked so well in other settings. The answer depends largely on one's definition of an "auction". If a sufficiently broad definition is used, then there can be no doubt that an optimal auction can be designed. However the result is likely to be something much closer to book building than to the types of procedures most people currently think of as auctions.

More research is also needed on hybrid methods, which are becoming increasingly common. By the end of the 1990s, hybrid book building/public offer may have become the most common IPO method worldwide, despite the fact that hybrids are still rare in the U.S. Little work has been done on how hybrids differ from pure book building.

Last, there is a need for more empirical research on IPO methods. The possibility that forcing issuers to use auctions may prevent some issuers from going public should be examined (following the example set by Kutsuna and Smith, 2001, for Japan). A related question is whether the IPO issuer mix has changed in countries such as France that made a more gradual transition from predominantly auctions to predominantly book building. The "customized" approach allowed by book building should lead to a wider range of deliberate underpricing levels, and to a wider range of issuers being able to access equity markets.

More attention should also be given to price adjustments during the first week of aftermarket trading. Academics tend to focus on the first aftermarket price (either the opening or closing price on the first day of trading). Lee, Lin and Liu (2003) have shown for Taiwan, however, that there was a systematic, statistically significant drop in price during the first few days of aftermarket trading following IPO auctions. This supports anecdotes for Japan and Singapore that the trading price tended to fall during the first few days of aftermarket trading following IPO auctions.

Attention should also be given to learning, over time, for IPO auctions. Many countries adopted auctions enthusiastically, used them for several years, then dropped them. How did the number of bidders and the initial return change over time? Lin, Lee and Liu show that, in Taiwan, auctions with low institutional participation have had large negative initial returns and fewer bidders, relative to auctions with more institutional participation and positive initial returns. Why would fewer bidders lead to more apparent overpricing? The problems with IPO auctions in other countries imply that WR Hambrecht has been lucky so far. Before the U.S. considers pushing issuers to use a method that has failed repeatedly elsewhere, we need a better understanding of the relevant advantages of the various methods. The paper attempts to contribute to the debate.

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Appendices

Appendix A. Information reporting or truth-telling constraints.

The full set of six truth-telling or information reporting constraints are given below, expanding equation (1). These conditions are discussed in Section 3.2.b.

$R_B(H,H) \geq R_B(H,M)$:

$$\sum_{k=1}^{K-1} P'(h,k)\,[(s^h - s_{H,H,k+1})q_{H,H,k+1} - (s^h - s_{M,H,k})q_{M,H,k}]$$
$$+ \quad P'(h,0)\,[(s^h - s_{H,H,1})q_{H,H,1} - (s^h - s_{M,M})q_{M,M}] \quad \geq \; 0 \qquad \text{(A1)}$$

$R_B(M,M) \geq R_B(M,L)$:

$$(1-\theta)\;\sum_{k=1}^{K-1} P'(\ell,k)\,[(s^\ell - s_{M,L,k})q_{M,L,k} - (s^\ell - s_{L,L,k+1})q_{L,L,k+1}]$$
$$+ \quad \theta \sum_{k=1}^{K-1} P'(h,k)\,[(s^h - s_{M,H,k})q_{M,H,k} - 0]$$
$$+ \quad P'(\cdot,0)\;\{\,(s^m - s_{M,M})\,q_{M,M} - (s^m - s_{L,L,1})\,q_{L,L,1})\,\} \quad \geq \; 0 \qquad \text{(A2)}$$

$R_B(H,H) \geq R_B(H,L)$:

$$\sum_{k=1}^{K-1} P'(h,k)[(s^h - s_{H,H,k})q_{H,H,k} - 0] \;+ P'(h,0)\{\,(s^h - s_{H,H,1})\,q_{H,H,1} - (s^h - s_{L,L,1})\,q_{L,L,1})\,\} \;\geq\; 0 \qquad \text{(A3)}$$

$R_B(M,M) \geq R_B(M,H)$:

$$\theta \sum_{k=1}^{K-1} P'(h,k)\,[(s^h - s_{M,H,k})q_{M,H,k} - (s^h - s_{H,H,k+1})q_{H,H,k+1}]$$
$$+ \quad (1-\theta) \sum_{k=1}^{K-1} P'(\ell,k)\,[(s^\ell - s_{M,L,k})q_{M,L,k} - 0]$$
$$+ \quad P'(\cdot,0)\;\{\,(s^m - s_{M,M})\,q_{M,M} - (s^m - s_{H,H,1})\,q_{H,H,1})\,\} \quad \geq \; 0 \qquad \text{(A4)}$$

$R_B(L,L) \geq R_B(L,M)$:

$$\sum_{k=1}^{K-1} P'(\ell,k)\,[(s^\ell - s_{L,L,k+1})q_{L,L,k+1} - (s^\ell - s_{M,L,k})q_{M,L,k}]$$
$$+ \quad P'(\ell,0)\,[(s^\ell - s_{L,L,1})q_{L,L,1} - (s^\ell - s_{M,M})q_{M,M}] \quad \geq \; 0 \qquad \text{(A5)}$$

$R_B(L,L) \geq R_B(L,H)$:

$$\sum_{k=1}^{K-1} P'(\ell,k)[(s^\ell - s_{L,L,k})q_{L,L,k} - 0] \;+ P'(\ell,0)\{\,(s^\ell - s_{L,L,1})\,q_{L,L,1} - (s^\ell - s_{H,H,1})\,q_{H,H,1})\,\} \;\geq\; 0 \qquad \text{(A6)}$$

Appendix B. Proof of Proposition 1

Proof of 1): The underwriter/issuer prefers the highest issue prices possible. The only constraints on prices to the uniformed are from the participation constraints of the uninformed, equation (4), which bind.

Proof of 2): Since $s^\ell = 0$, ℓ shares cannot be underpriced in this model. More generally, however, the truth telling restrictions for H will always bind before the truth-telling restrictions for L, because $s^\ell < s_{M,M}$ and $s^\ell < s_{H,H,k}$ except under extreme underpricing, whereas

$s^h > s_{M,M}$ and $s^h < s_{L,L,k}$ unless there is overpricing. This makes it more efficient for the underwriter to compensate investors through underpricing of H rather than L shares.

Proof of 3): As long as prices are non-negative and no shares are strictly overpriced, equations (A5) and (A6) will not bind. Similarly, (A2) and (A3) will not bind as long as $q_{L,L,l} = 0$. Thus, of the truth-telling constraints, only (A1) and (A4) may affect the equilibrium.

Underpricing to those that report M lowers the expected proceeds of the issuer/underwriter. It will also make it easier to satisfy (A4), but in constraints (2), (A1) and (A4), only the differences between the returns to those that report H and the returns to those that report M show up. Thus, to satisfy these constraints, a decrease in the expected return to those that report H has the same effect as an increase in the expected return to those that report M. Since a decrease in expected return to those that report H is always at least as good in terms of satisfying the constraints, and it strictly dominates in terms of maximizing the underwriter's expected proceeds, it will always be strictly preferred (and therefore chosen) by the underwriter.

Appendix C. Proof of Proposition 2

First, the two cumulative bidding distributions are as follows.

$M_D(b;\alpha,p)$ is the unique positive real root of the polynomial:

$$\theta\,(1-b)[1-p+p(1-\alpha)\,M_D(b;\alpha,p)]^{N-X} - b\,(1-\theta)[1-p\,(1-\alpha)+p(1-\alpha)\,M_D(b;\alpha,p)]^{N-X} - \theta\,(1-p)^{N-X} \tag{A7}$$

for $b \in (\underline{m}_D, \overline{m}_D]$ and

$$H_D(b;\alpha,p) = \frac{1-\alpha p}{\alpha p}\left(-1+\left(\frac{1-\theta+\theta(1-p)^{N-X}}{(1-b)\,[1-\theta+\theta(1-p\alpha)^{N-X}]}\right)^{1/(N-X)}\right)$$

for $b \in (\underline{h}_D, \overline{h}_D]$, where $M_A(b;\alpha,p)$ is the cumulative distribution function (cdf) for bidders that observe signal M and $H_A(b;\alpha,p)$ is the cdf for bidders that observe signal H, $A \in \{D, U\}$. The limits to the bidding ranges are: $\underline{m}_D = 0$,

$$\overline{m}_D = \underline{h}_D = \frac{\theta\,[(1-p\alpha)^{N-X} - (1-p)^{N-X}]}{1-\theta+\theta\,(1-p\alpha)^{N-X}}$$

and

$$\overline{h}_D = 1 - (1-p\alpha)^{N-X}\,\frac{1-\theta+\theta\,(1-p))^{N-X}}{1-\theta+\theta(1-p\alpha)^{N-X}}$$

To demonstrate that this is the solution to the auction, I need to show that the bidders are acting optimally through their choice of the equilibrium p, α pair in stage 1 and through the bidding strategies given for stage 2. The way p and α are chosen (i.e. such that $PC_D(\alpha,p)$ and $FOC_D(\alpha,p)$ are zero) guarantees that they are optimal for stage 1. For stage 2, note that the expected profit to bidding $b \in (\underline{m}_D, \overline{m}_D)$ with signal M (recall that this is expected profit *after* information has been purchased) is:

$R_D(b|M)$ =

$$\theta\,(1-b)\sum_{j=0}^{X-1}\sum_{i=0}^{N-1-j}\binom{N-1-j}{i}\binom{X-1}{j}(1-p)^{N-1-i-j}\,[\alpha p+(1-\alpha)p(1-M_D(b;\alpha,p)]^{j}\,[p(1-\alpha)M_D(b;\alpha,p)]^{i}$$

$$-\,b\,(1-\theta)\sum_{j=0}^{X-1}\sum_{i=0}^{N-1-j}\binom{N-1-j}{i}\binom{X-1}{j}(1-p)^{N-1-i-j}\,[\alpha p+p(1-\alpha)M_D(b;\alpha,p)]^{i}\,[p(1-\alpha)(1-M_D(b;\alpha,p))]^{j}$$

The first set of terms are: the probability that the issue has a high value (θ) times the profit to winning and thus paying b for shares worth one ($1-b$), times the probability of winning with bid b, given that the firm is type H. This last probability is the sum over all combinations of bids that could lead to b being a winning bid, given that the firm is type H. Of the other N-1 bidders, j (between 0 and X-1) either receive signal H and bid above (with probability αp), or receive signal M and bid above (with probability $(1-\alpha)p(1-M(b;\alpha,p))$; i other bidders (between 0 and N-1-j) receive signal M and bid below (with probability $p(1-\alpha)M_D(b;\alpha,p)$); and the remaining N-1-j-i other bidders do not enter the auction (with probability 1-p). If more than X-1 other bidders bid above you, you do not have a winning bid and thus get zero.

The second set of terms is: the expected loss to paying b for shares worth nothing (-b) times the probability that the shares are type L and thus worth nothing ($1-\theta$), times the probability of winning with bid b, given that the firm is type L. Again, the probability is the sum over all combinations of bids for the N-1 other bidders that lead to b being a winning bid, given the firm's type. The key difference in the second probability of winning is that, when the firm is type L, bidders that receive an informative signal will bid below, not above, bidders that observe M. We can rewrite the expected profit for investors with a neutral signal as:

$$R_D(b|M) = \theta\,(1-b)[1-p+p(1-\alpha)\,M_D(b;\alpha,p)]^{N-X} - b\,(1-\theta)[1-p\,(1-\alpha)+p(1-\alpha)\,M_D(b;\alpha,p)]^{N-X}$$

An investor that gets a neutral signal has a riskless alternative to bidding in the range from $\underline{m}_D$ to $\overline{m}_D$, and that is to bid the lowest possible share value, which in this case is zero. Because entry is endogenous, there is a chance that not enough other bidders will enter the auction, and therefore that such a bid will win. The bid is riskless, because even low value shares are worth zero, while high value shares are worth strictly more. Since bids are accepted at this minimum value, the expected return to bidding $b \in (\underline{m}_D, \overline{m}_D)$ must be at least as great as the expected return to bidding zero, given that a bidder receives a neutral signal. The expected profit to bidding zero in this auction is $\theta\,(1-p)^{N-X}$, since a bid of zero is successful only if less than X other bidders choose to enter the auction. Thus, $R_D(b|M) = \theta\,(1-p)^{N-X}$. Setting this version equal to our earlier formula for $R_D(b|M)$ gives us equation (A7).

From equation (A7), we can also find $\underline{m}_D$ and $\overline{m}_D$. For bidders to be willing to bid anywhere in the range $\underline{m}_D$ to $\overline{m}_D$, the expected profits must be the same for all bids. Since $M_D(b;\alpha,p)$ is the cumulative density function for the bids, we know that $M_D(\overline{m}_D;\alpha,p) = 1$, and $M_D(\underline{m}_D;\alpha,p) = 0$. Plugging these into (A7) tells us that the lower end of the distribution is zero, and the upper end is given by equation ***

The expected profit to bid $b \in (\underline{h}_D, \overline{h}_D)$ with signal H in the discriminatory auction is

$R_D(b|H)$ =

$$(1-b)\sum_{j=0}^{X-1}\sum_{i=0}^{N-j-1}\binom{N-1-j}{i}\binom{X-1}{j}(1-p)^{N-j-1-i}\,(\alpha p(1-H_D(b;\alpha,p))^{j}\,[p(1-\alpha\,(1-H_D(b;\alpha,p)))]^{i}$$

$= (1-b)\,[1- \alpha\, p\,(1 - H_D(b;\alpha,p)))]^{N-X}$

The expected profit must be the same for all bids in the range $\underline{h}_D$ to $\bar{h}_D$(since investors otherwise would not be willing to bid anywhere within the range. An investor with signal H that bids at the top of the range, $\bar{h}_D$, wins with probability one and gets a payoff of $1 - \bar{h}_D$. An investor with signal H that bids at the bottom of the range will only win if less than X other bidders enter and receive H (since all other bidders with H will bid above $\underline{h}_D$). The payoff if the bid wins is $1 - \underline{h}_D$, and the probability of winning is $(1 - \alpha p)^{N-X}$. Thus, we know that

$$1 - \bar{h}_D = (1 - \underline{h}_D)\,(1 - \alpha p)^{N-X}.$$

It must also be true that $\underline{h}_D = \bar{m}_D$ (if not, bidders with H could lower their bids, increasing their payoff if they win without changing their chance of winning, which would make the higher bids suboptimal). All of this allows us to obtain the formulas for $H_D(b;\alpha,p)$ and $\bar{h}_D$ given earlier.

Last, it is straightforward to show that bidding $b \in (\underline{h}_D, \bar{h}_D)$ with signal M or bidding $b \in (\underline{m}_D, \bar{m}_D]$ with signal H would lead to a lower expected return, meaning that the bidding strategy given in Proposition 2 is optimal.

In the uniform price auction, $\underline{h}_U = \bar{h}_U = 1$. Bidders that receive an H signal will bid the full value of the shares, but of course they will pay the X + 1st price. Let Z be the expected X + 1st or clearing price. The expected profit to a bid of one, given signal H, is:

$$R_U(b|H) = \sum_{i=0}^{X} \binom{N-1}{i} (p)^i (1-p)^{N-1-i}$$

$$+ \int_{\underline{m}}^{\bar{m}} (1 - z)\, p\,(1-\alpha)\, m_U(z) \sum_{j=0}^{X-1} \binom{X-1}{j} (\alpha p)^j [p\,(1-\alpha)\,(1-M_U(z;\alpha,p))]^{X-1-j}$$

$$* \sum_{i=0}^{N-X-1} \binom{N-X-1}{i} (1-p)^i\, [p\,(1-\alpha)\, M_U(z;\alpha,p)]^{N-1-X-i}\, dz$$

where $m_U(z)$is the probability density function (pdf) of a bid $z \in [\underline{m}_U, \bar{m}_U]$, and $M_U(z;\alpha,p)$ is the cdf, as defined earlier.

The first set of terms in $R_U(b|H)$ represent the probability that the number of entrants to the auction is less than or equal to X, meaning that the price paid by all bidders will be the reservation price (since there is no X + 1st price). As mentioned earlier, the reservation price in this model is the lowest possible value of the stock, zero.

Second, we have the integral over possible reservation prices, $z \in [\underline{m}_U, \bar{m}_U]$, of the expected profit to buying shares at the X+1st price (1-z) times the probability of price z being the X+1st price. For price z to be the X+1st bid (actually the Xth of the N-1 other potential bids, given that this bidder receives a signal H and bids 1.0), there must be one bid at z (with probability $p\,(1-\alpha)\, m_U(z)$), j (between 0 and X-1) that enter, receive signal H and bid above z (with probability αp), X-1-j that enter, receive signal M and bid above z (with probability $p(1-\alpha)(1-M_U(z;\alpha,p))$), i (between 0 and N-X-1) bidders that do not enter (with probability 1-p), and N-1-X-i bidders that enter, receive signal M and bid below z (with probability $p(1-\alpha)M_U(z;\alpha,p)$). If X or more other bidders enter and get signal H, then the X+1st price will be 1.0, and there will be no profit.

The pdf of the X+1[st] price, given signal H, is:

$$f^{H}(z) = p(1-\alpha)\, m_U(z) \sum_{j=0}^{X-1} \binom{X-1}{j} (\alpha p)^j [p(1-\alpha)(1 - M_U(z;\alpha,p))]^{X-1-j}$$

$$* \sum_{i=0}^{N-X-1} \binom{N-X-1}{i} (1-p)^i [p(1-\alpha) M_U(z;\alpha,p)]^{N-1-X-i}$$

$$= p(1-\alpha)\, m_U(z) [p - p(1-\alpha) M_U(z;\alpha,p)]^{X-1}[1 - p + p(1-\alpha) M_U(z;\alpha,p)]^{N-1-X}.$$

And the probability of undersubscription in the auction (which is equal to the expected profit due to the issue price being equal to the reservation price) is:

$$P(\text{undersubscription}) = \sum_{i=0}^{X} \binom{N-1}{i} (p)^i (1-p)^{N-1-i}$$

These definitions allow us to rewrite the expected profit, given a signal of H, as:

$$R_U(b|H) = P(\text{undersubscription}) + \int_{\underline{m}}^{\overline{m}} (1-z)\, f^{H}(z)\, dz.$$

Similarly, the expected profit to bidding $b \in (\underline{m}_U, \overline{m}_U)$ in a uniform price auction, given that signal M has been observed, is:

$$R_U(b|M) = \theta\, P(\text{undersubscription}) + \theta \int_{\underline{m}}^{b} (1-z)\, f^{H}(z)\, dz - (1-\theta) \int_{\underline{m}}^{b} z\, f^{L}(z)\, dz.$$

where $f^{L}(z)$ is the pdf of the X+1[st] price, z, given that the firm is type L, which is:

$$f^{L}(z) = p(1-\alpha)\, m_U(z) [p(1-\alpha)(1 - M_U(z;\alpha,p))]^{X-1}[1 - p(1-\alpha)(1 - M_U(z;\alpha,p))]^{N-1-X}.$$

In other words, the expected return to a bidder with an M signal is equal to the probability that the issue is type H times the expected profit to winning the bid and buying shares, given that the issue is type H (this includes both the probability that the issue is undersubscribed and thus that the share is purchased for zero, and the probability that the X+1[st] price, z, is less than b), plus the probability that the issue is type L times the expected loss (- z) to winning the bid and buying shares, given that the issue is type L.

Besides the fact that bidders that receive a neutral signal do not know the value of the shares and thus might lose money by bidding too much, this expected profit term differs from that for bidders that receive signal H because the integration goes only up to that bidder's bid, b, rather than to the upper limit of the bidding range, $\overline{m}_U$. This is because the bidder wins a share only if her bid, b, is greater than the reservation price, z. Bidders that get an H signal bid the maximum amount, 1.0, and thus they may fail to win shares only in the case that at least X other bidders also bid 1.0, in which case the price is equal to the value of the shares, and the bidder is indifferent to winning an allocation.

For bidders with signal M to be willing to bid anywhere within the range from $\underline{m}_U$ to $\overline{m}_U$, the expected profit must be the same for all bids within the range. In other words, the derivative of $R_U(b|M)$ with respect to b must equal zero. This gives us the restriction that:

$$\theta(1-b)\, f^{H}(b) = (1-\theta)\, z\, f^{L}(z) \quad \text{for all } b \in (\underline{m}_U, \overline{m}_U).$$

Substituting this into $R_U(b|M)$ and simplifying yields:

$R_U(b|M) \;=\; \theta\, P(\text{undersubscription}).$

Note that, holding p constant, $R_U(b|M)$ (which equals θ P(undersubscription)) is strictly greater than $R_D(b|M)$ (which equals $\theta\ (1\text{-}p)^{N\text{-}X}$). In a discriminatory auction, only those that actually bid the reservation price get to pay the reservation price, whereas in a uniform price auction other bidders will also pay the reservation price if the auction is undersubscribed (i.e. if less than X+1 choose to enter).

Substituting into these equations reveals that $\bar{m}_U = 1.0$ and

$$\underline{m}_U = \frac{\theta\, p^{X-1}(1-p)^{N-X-1}}{\theta\, p^{X-1}(1-p)^{N-X-1} + (1-\theta)[p(1-\alpha)]^{X-1}[1-p(1-\alpha)]^{N-X-1}}$$

Again, it is straightforward to show that bidding $b \in (\underline{m}_U, \bar{m}_U)$ with signal H would lead to a lower expected return, meaning that the bidding strategy given in Proposition 2 is optimal.

Appendix D. Proof of Proposition 3

First, I will derive SER_B:

Given Prop. 1, we can rewrite (2), (A1) and (A4) (the only potentially binding constraints) as:

$$\theta \textstyle\sum_{k=1}^{K} P'(h,k\text{-}1)\,(s^h - s_{H,H,k})q_{H,H,k} \;\geq\; (1/\alpha)\,(C(\alpha) + e) \qquad (2')$$

$$\textstyle\sum_{k=1}^{K} P'(h,k\text{-}1)\,(s^h - s_{H,H,k})q_{H,H,k} \;\geq\; 0 \qquad (A1')$$

$$-\,\theta \textstyle\sum_{k=1}^{K} P'(h,k\text{-}1)\,(s^h - s_{H,H,k})\dot{q}_{H,H,k} + P'(\cdot,0)\,(1-\theta)\, s_{H,H,1}\, q_{H,H,1} \;\geq\; 0 \qquad (A4')$$

(A1') won't bind as long as (2') is satisfied, since $C(\alpha) + e > 0$. (A4) will limit the degree of overpricing, meaning that there is a feasibility limit to how much info. the issuer can purchase/induce. Equation (2) gives a minimum amount of underpricing for a given level of information collection. It will always bind, so we can substitute the amount of underpricing from (2) into SER_B, giving us the equation shown in Proposition 3.

For SER_A:

This formula follows directly from the fact that bidders choose α and p such that both PC_A and FOC_A equal zero (i.e. such that their ex ante expected profit equals zero).

Appendix E. Proof of Proposition 4

Since expected evaluation costs are the same for the two methods, It is sufficient to show that

$$\left(1 - \textstyle\sum_{i=0}^{X-1} P(\text{entry} = i)\left(1 - \dfrac{i}{X}\right)\right) < 1$$

which follows from $i/X < 1$, $N \geq X$ and $\sum_{i=0}^{N} P(\text{entry} = i) = 1$.